Temporal Constraints on and Vertical Injections of Biomass Burning Emissions: Implications on Global Aerosol Simulations

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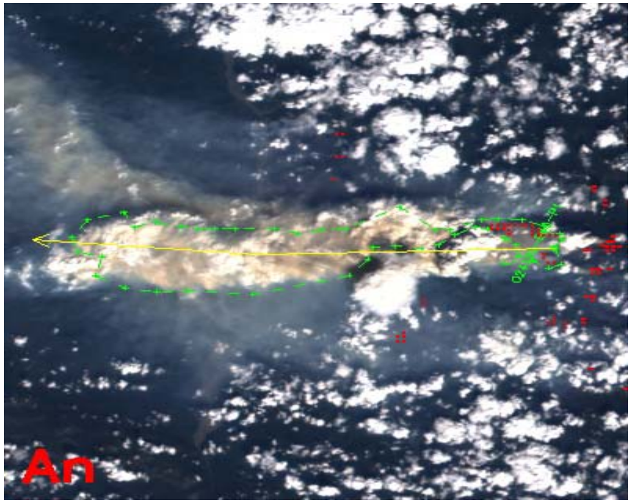
EOS Aura Science Team Meeting
Oct 5, 2007@ Pasadena, CA

Introduction

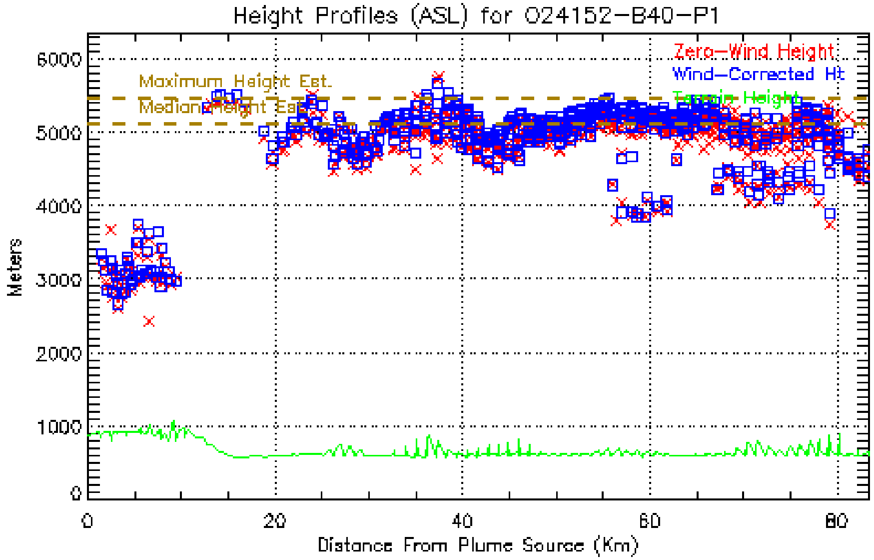
- **Observations have shown smoke plumes being injected to the upper troposphere through 'pyro-convection' (e.g. Fromm et al., 2005).**
- **Proper treatment of vertical injection of biomass burning emissions is critical for assessing the regional to global impact of wild fires.**
  - In previous studies, biomass burning emissions were
    - Emitted only into the boundary layer **OR**
    - Arbitrarily distributed throughout the tropospheric column (e.g., Cook et al., 2007; Matichuk et al., 2007; Turquety et al., 2007)
  - This study: we derive a vertical distribution profile of biomass burning emissions based on Multi-angle Imaging Spectro-Radiometer (MISR) smoke plume injection heights.

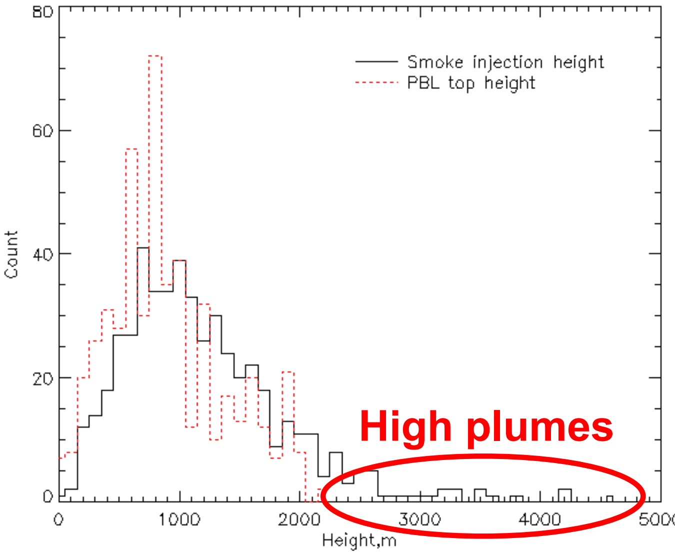
MISR smoke plume injection height



Based on injection heights of ~700 smoke plumes observed by MISR over Alaska in summer 2004, we derived a probability distribution function (pdf) of biomass burning emission vertical injection. **Emissions are vertically distributed according to the pdf.**

• [***Ongoing simulation***] Treat the emissions from individual high-altitude smoke plumes as we treat emissions (say, SO_2) from volcano eruptions.



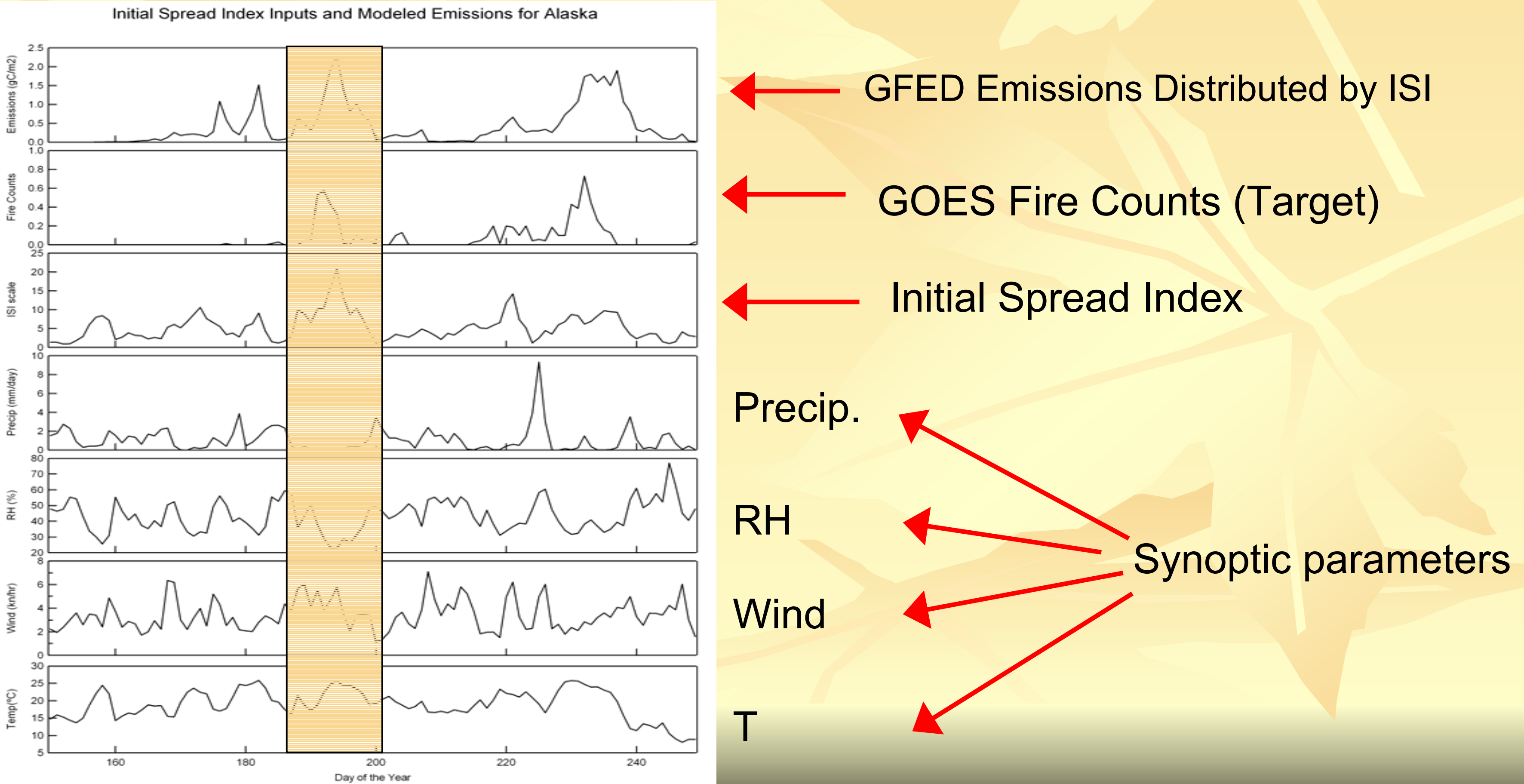


Introduction

- Wild fires exhibit strong diurnal variability. Their intensity and duration are influenced by synoptic weather systems.
- These temporal constraints on biomass burning emissions are generally not included in CTMs.
- **How important are these temporal constraints, say, relative to the inclusion of vertical injection height?**
- **Global Fire Emissions Database version 2 (GFEDv2)**
  - monthly
  - 8day

Biomass Burning Emissions: Diurnal Cycle and Synoptic Variability

- A mean diurnal cycle was derived for different geographic regions, based on GOES Automated Biomass Burning Algorithm (ABBA).
- Initial Spread Index (ISI) was computed using GMAO GEOS-4 reanalysis meteorological fields (T, RH, wind speed, and precipitation). Biomass burning emissions are redistributed within each 8-day period according to the ISI.



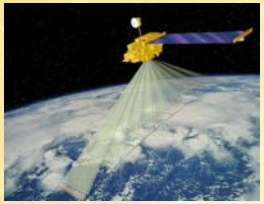
GEOS-Chem Simulations

- GEOS-Chem v7-04-10
- GMAO GEOS-4 reanalysis (2×2.5)
- (Offline) aerosol and tagged CO simulations for summer 2004

	Base emission inventory	Diurnal cycle	Synoptic variability	Vertical injection height	Doubling emissions
monthlyGFED	Monthly				
8dayGFED	8day				
diurnalGFED	8day	Yes			
synopGFED	8day	Yes	Yes		
verticalGFED	8day	Yes	Yes	Yes	
DBGFED	8day				Yes

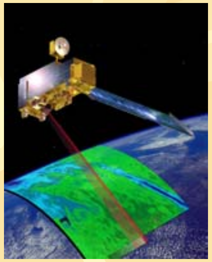
Observations

Satellite



MISR – AOD

MODIS – AOD



MOPITT – CO column

Aircraft

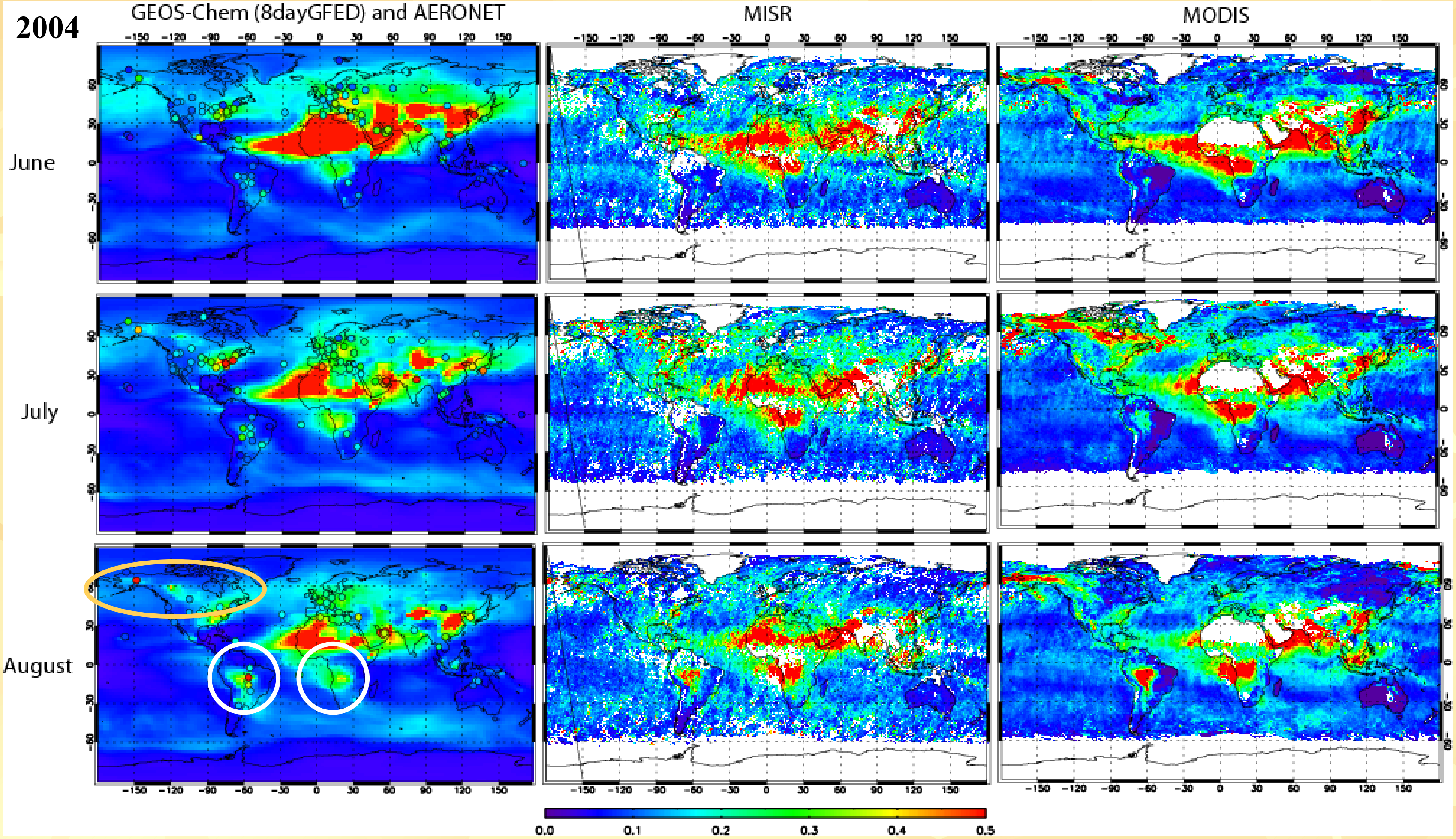
INTEX-NA – vertical profiles of aerosols and CO

Surface

AERONET – AOD

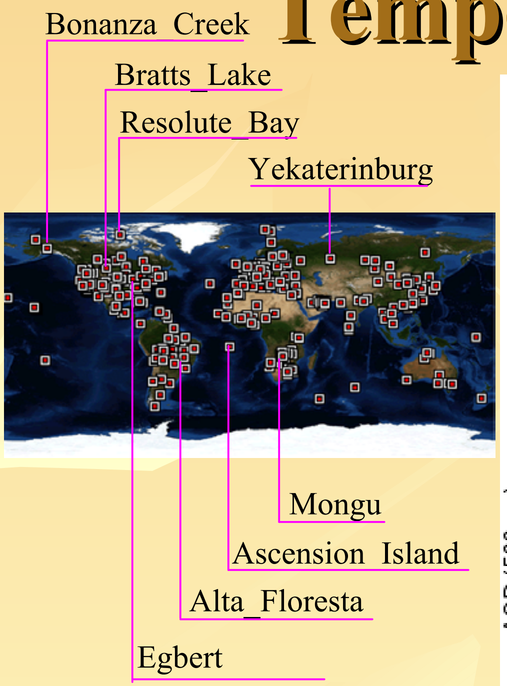
IMPROVE – surface aerosol concentrations

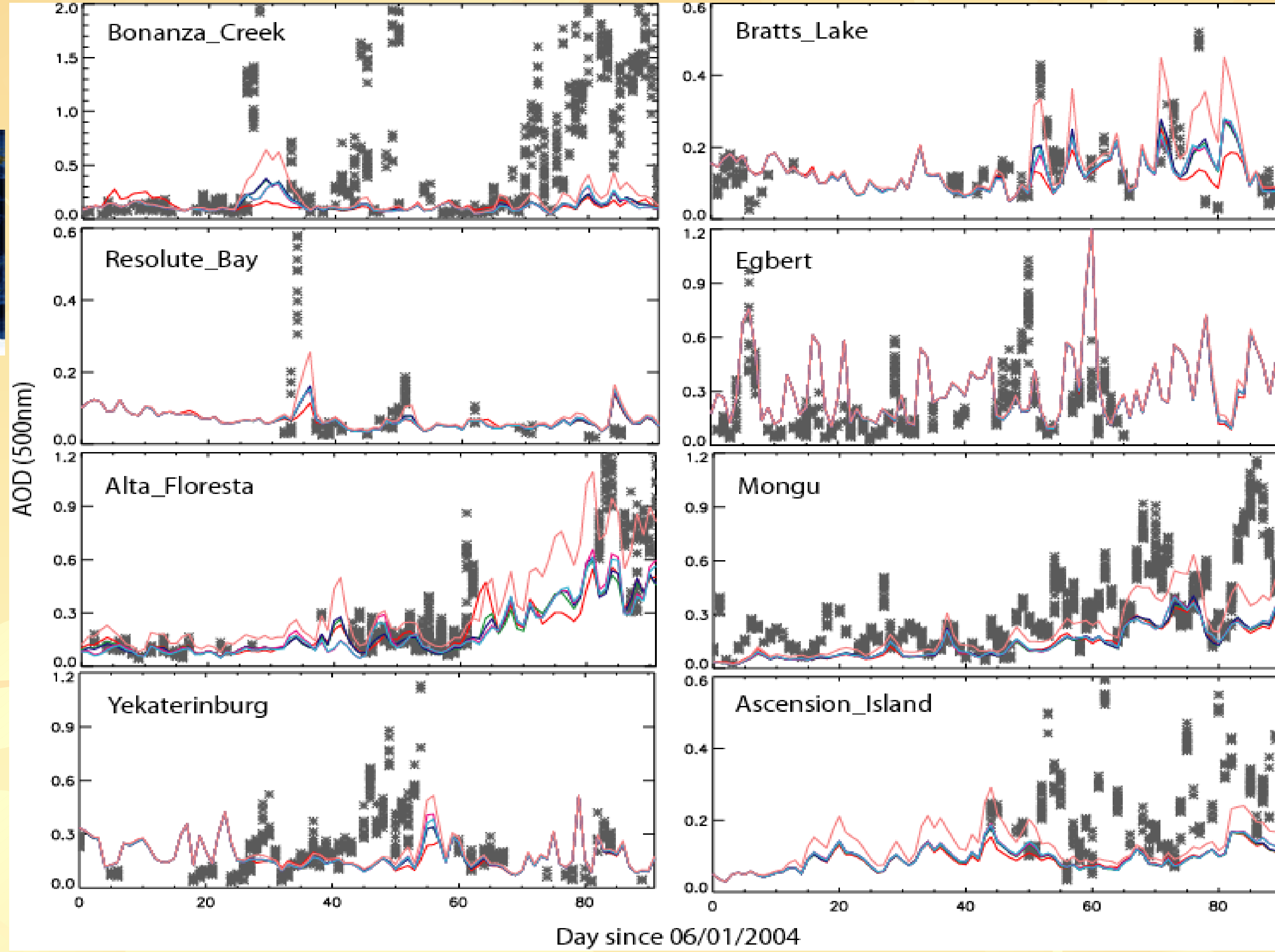
Monthly Mean AOD (~550nm), JJA 2004



Model simulations underestimate AODs in the biomass burning source and downwind regions (e.g., Alaska and southern Africa).

Temporal variability of AOD (500nm)

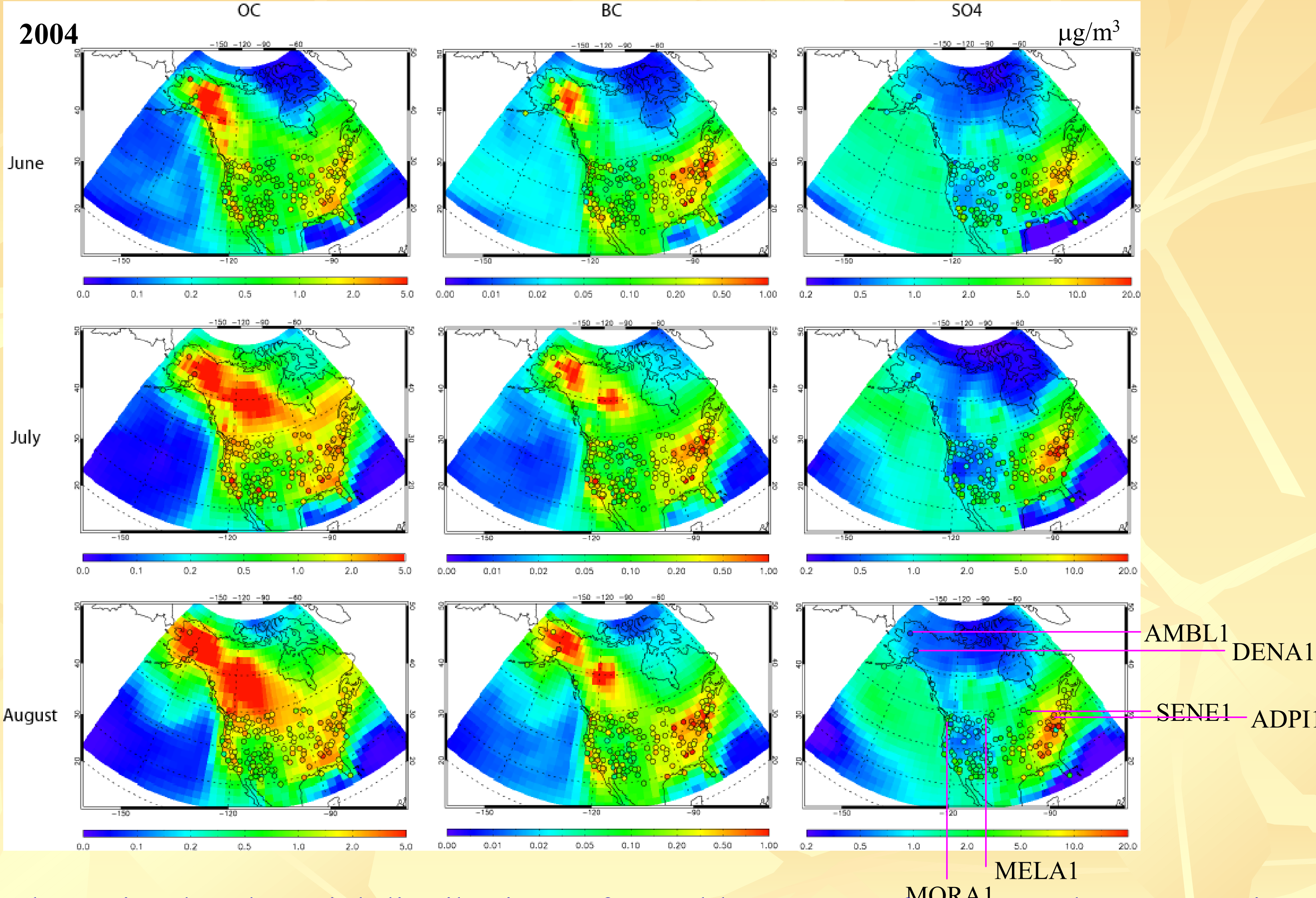




- AERONET
- monthly
- 8day
- diurnal
- synoptic
- vertical
- DB

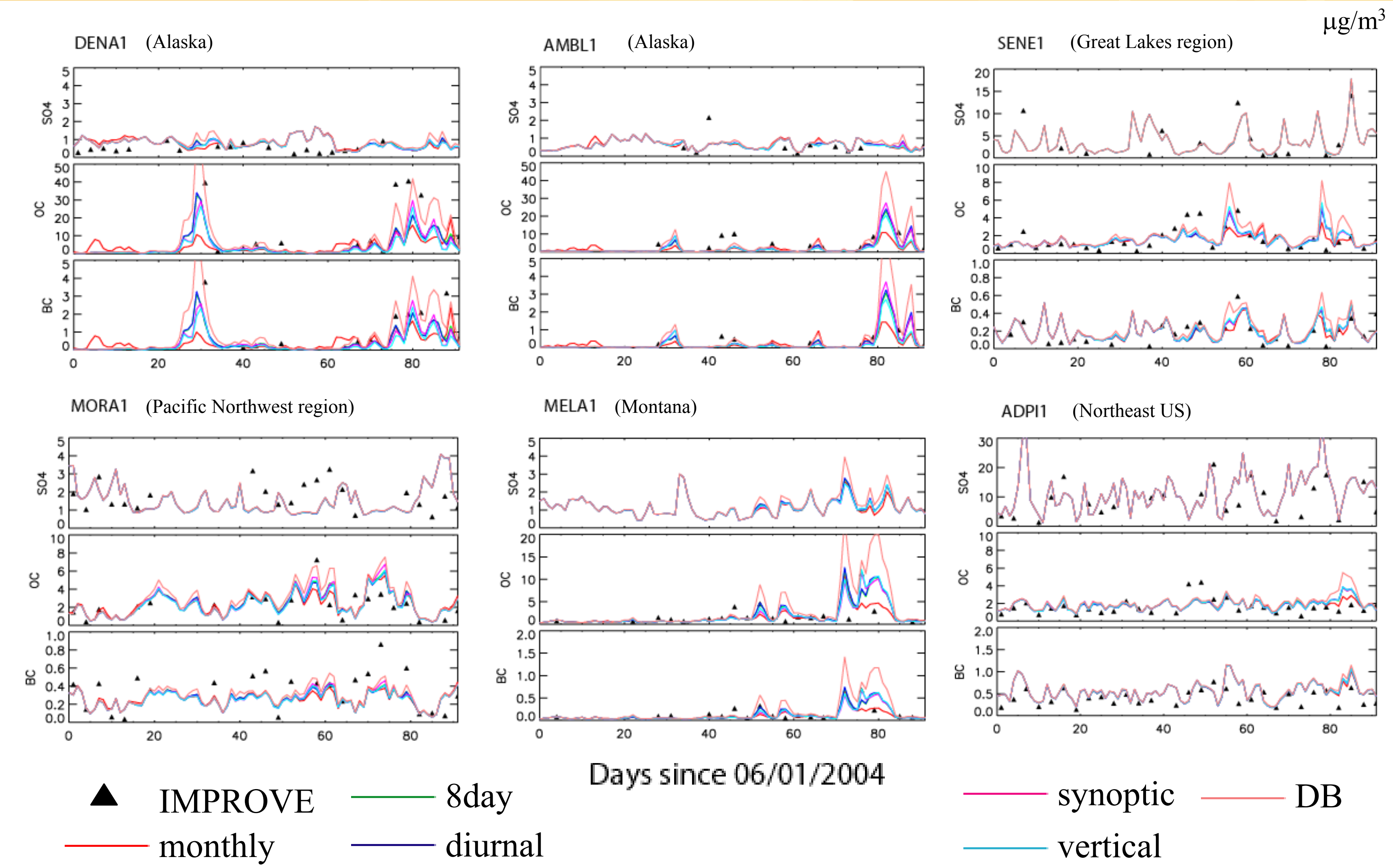
Model simulations (8day GFED based) capture the day-to-day variability of AOD but miss some high values.

Surface Aerosol Concentrations



GEOS-Chem simulated spatial distributions of monthly mean surface aerosol concentrations are in reasonable agreement with observations from the IMPROVE network, including over the biomass burning source regions.

Day-to-day Variability of Surface Aerosol Concentrations



• Good correlations between model simulations (8dayGFED based) and IMPROVE observations.

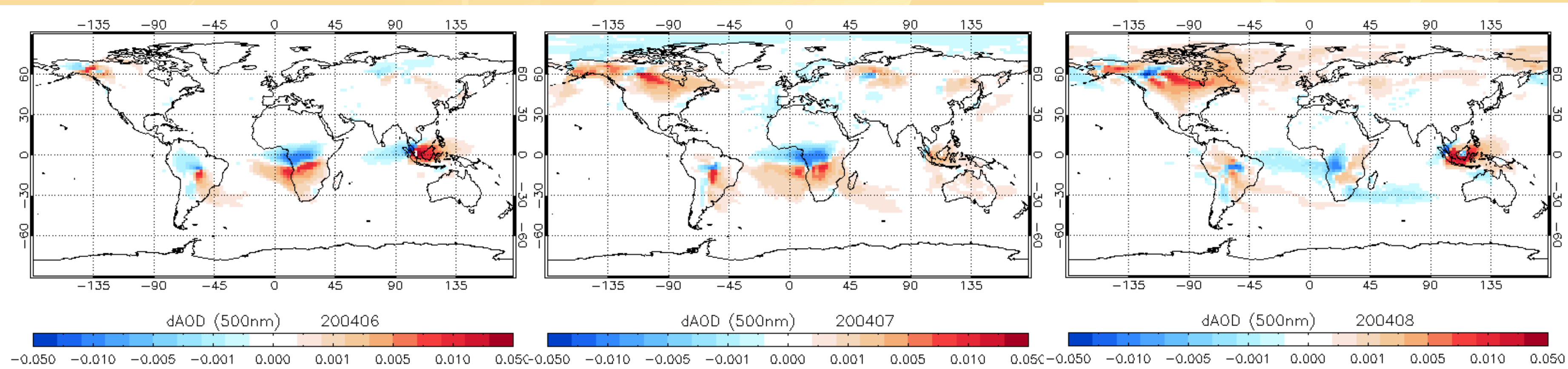
• Surprisingly, imposing diurnal cycle, synoptic variability, and vertical injection height (**as implemented here**) has small effect on the simulated day-to-day variability of surface aerosols.

Combined Effect of Additional Constraints

(diurnal cycle, synoptic variability, vertical injection)

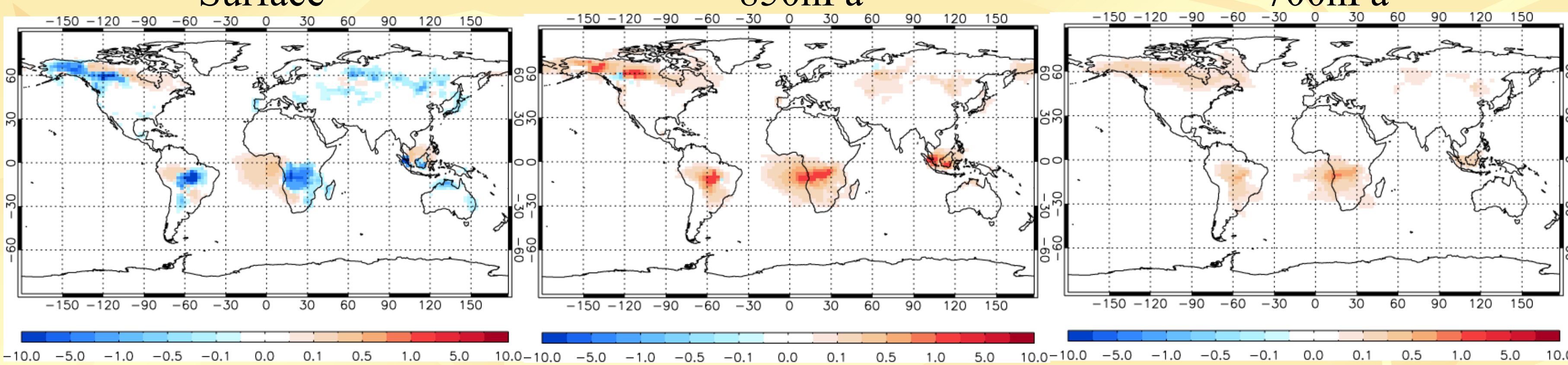
AOD

June | July | August



OC concentration (JJA)

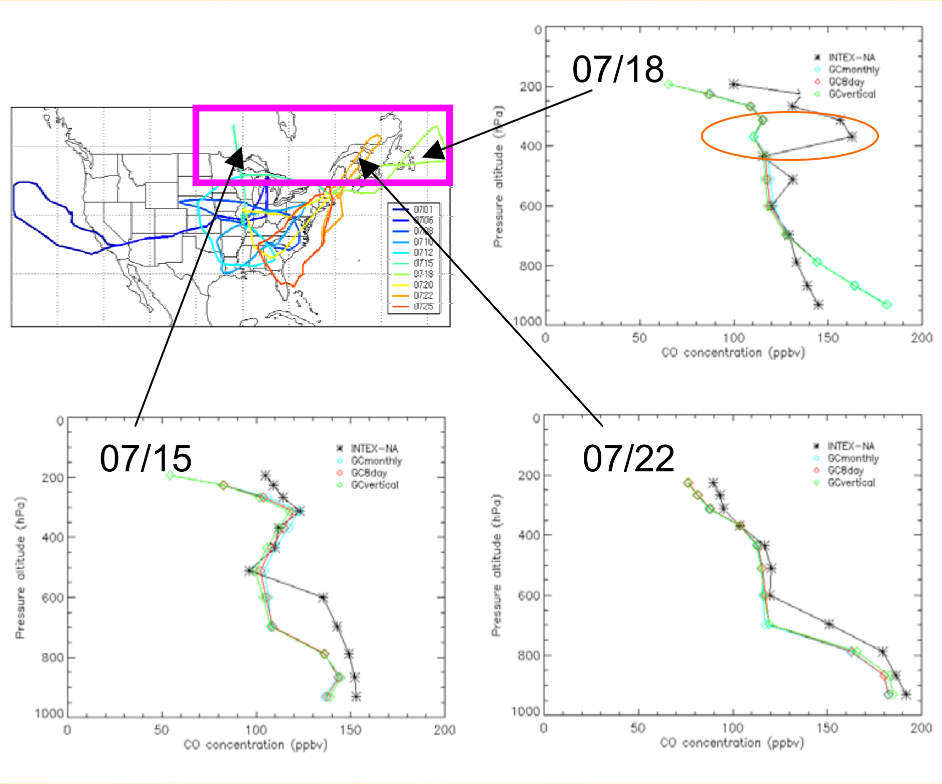
Surface | 850hPa | 700hPa



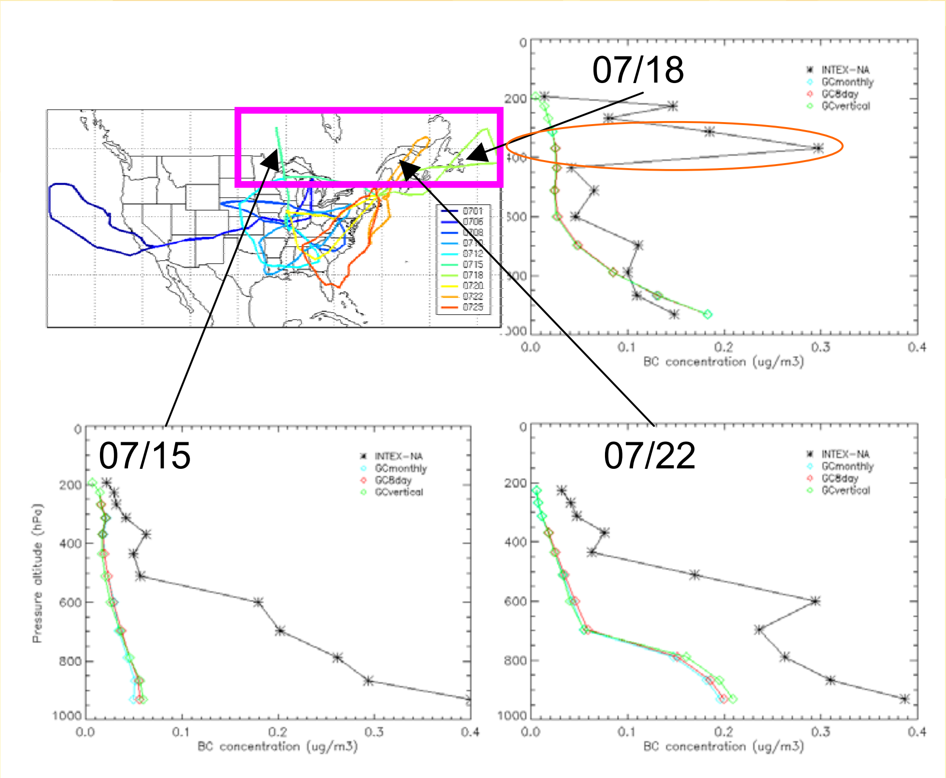
Increased transport of biomass burning emissions out of the boundary layer (over the source regions) to high altitudes and downwind of the source regions.

Vertical distribution of CO and BC: Comparison with INTEX-NA Observations

CO mixing ratio



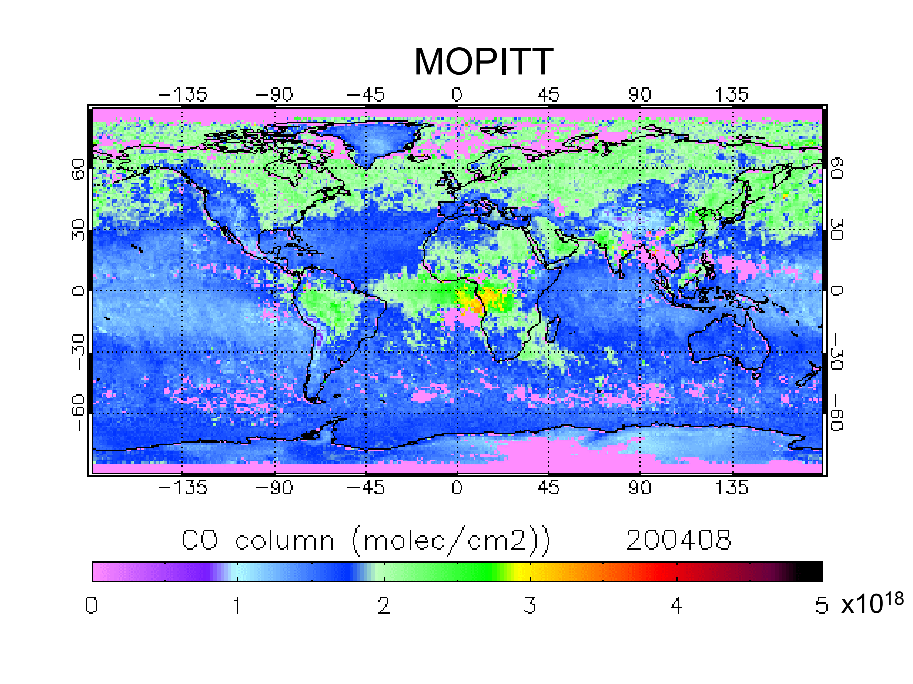
BC mass concentration

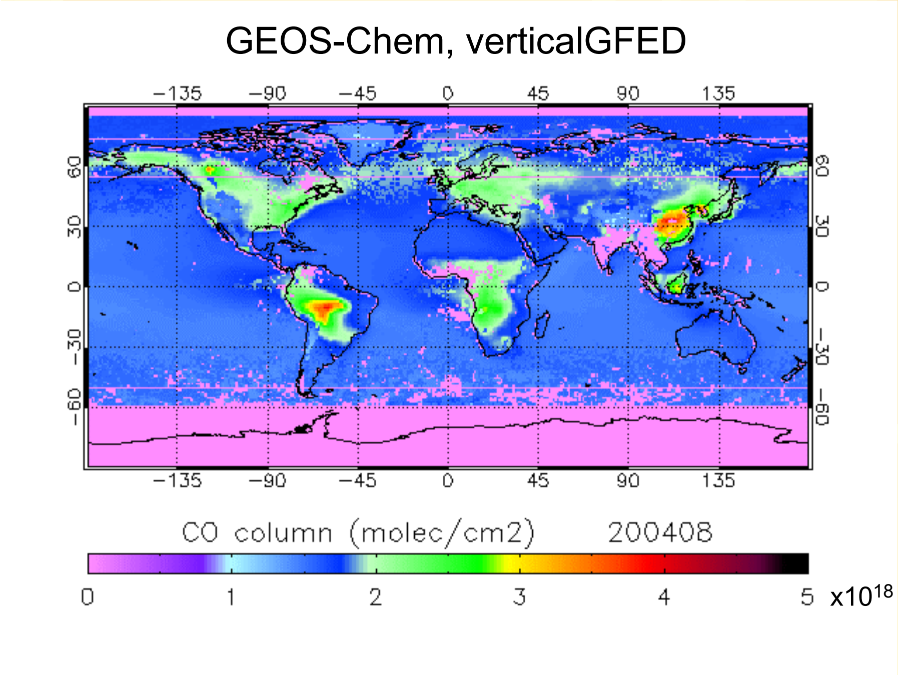


Despite good correlations in modeled and measured vertical profiles, the model simulations (even with vertical injection height) are not able to reproduce the high CO and BC concentrations at ~400 hPa during the July 18, 2004 flight.

BC mass concentrations were converted from aerosol absorption coefficient (m^{-1}) using a mass absorption efficiency of 7 m^2/g following Park *et al.* [2005].

CO column





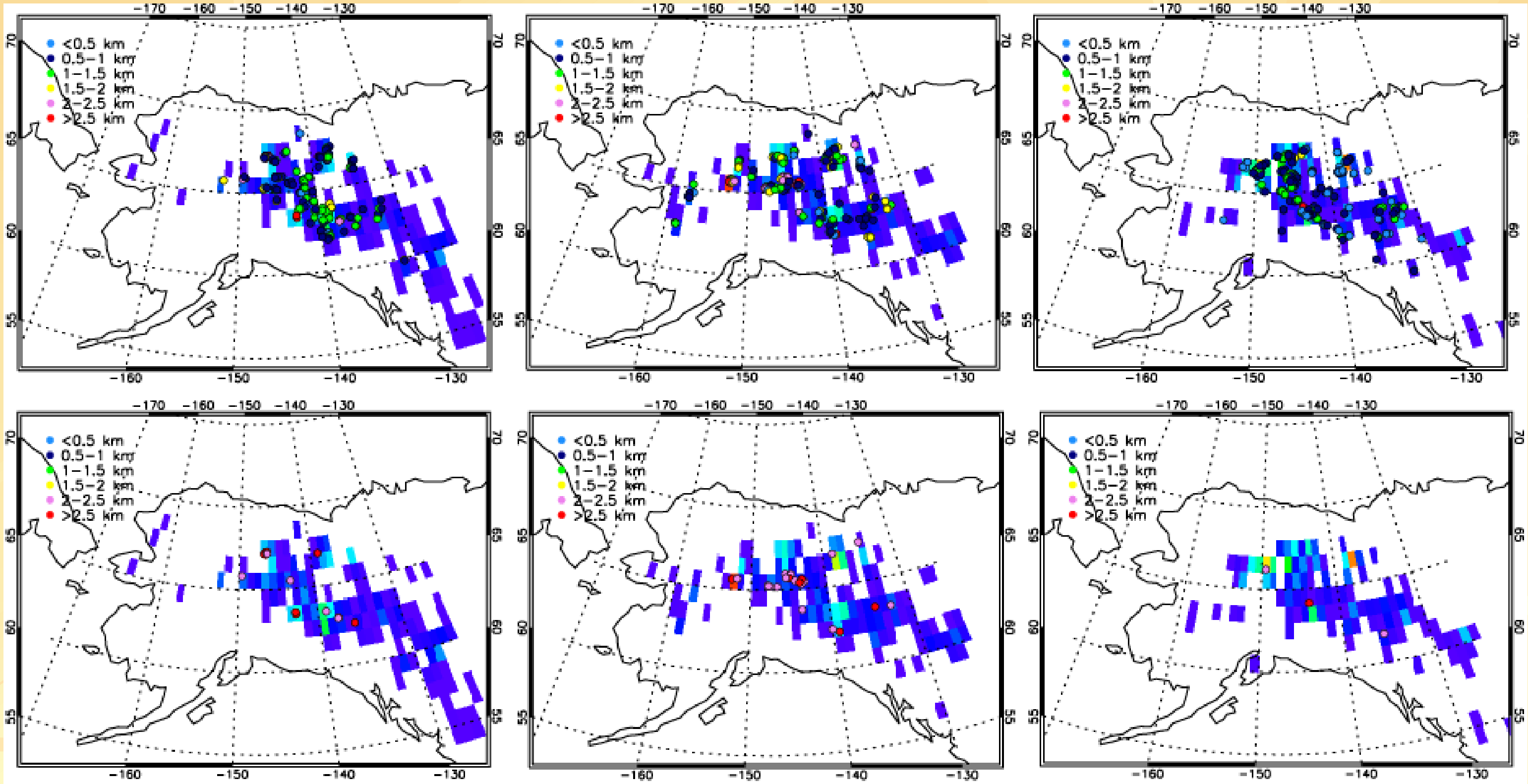
- MOPITT CO column is sensitive to middle-to-upper troposphere atmosphere
- Model simulations underestimate CO column compared to MOPITT

Treat 'Deep-convective' Smoke Plumes as Volcano Eruptions?

June July August

All smoke plume from the MISR database

High smoke plumes from the database



- For a model grid in which high smoke plumes are identified (by MISR), we distribute (all) the biomass burning emissions according to the (MISR-estimated) injection height.
- Biomass burning emissions in other grids are distributed vertically according to the pdf we derived from the MISR smoke plume database.
- There is some correlation between the emissions and injection height - a way to deal with (extrapolate) cases where no MISR data are available?

Summary

- Using 8-day instead of monthly biomass burning emissions significantly improves the comparison of mass concentrations of BC, OC, and sulfate with observations.

- The inclusion of diurnal cycle, synoptic variability, and vertical injection height in biomass emission inventory leads to more efficient transport of aerosols/CO out of the boundary layer, resulting in lower aerosol/CO loadings over the biomass source regions and higher loadings downwind.

- Spatial distribution and day-to-day variations of surface aerosol concentrations agree well with the observation. But current model simulations underestimate the AOD, CO column, and high altitude aerosol/CO concentrations in the downwind regions. A more realistic treatment of smoke injection height may improve the simulation.